Evaluation of Nutritional and Toxicological Significance of Essential Metals and Iodine in Vegetables and Spices from Kogi Metropolis,1 Nigeria

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Research Article

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Abstract

A study was conducted in Kogi Metropolis, Nigeria, to evaluate the levels of iodine and selected essential elements – calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) – across four widely consumed vegetables and spices, namely *Amaranthus hybridus* (smooth amaranth), *Allium sativum* (garlic), *Lactuca sativa* (garden lettuce), and *Ocimum gratissimum* (African basil). Iodine quantification was performed using UV–Visible spectrophotometry, while the elemental composition was assessed via Atomic Absorption Spectroscopy (AAS). The results indicated that garlic and African basil exhibited the greatest concentrations of calcium (122.22 ± 9.62 mg/kg) and iron (7.25 ± 0.97 mg/kg), respectively. Conversely, garden lettuce and smooth amaranth showed the lowest levels of calcium (61.11 ± 9.62 and 72.23 ± 9.62 mg/kg, respectively). Smooth amaranth recorded the greatest magnesium content, measured at 74.56 ± 0.41 mg/kg, while garlic had the lowest value of 52.15 ± 0.93 mg/kg. Zinc levels ranged from 1.41 ± 0.49 mg/kg in garden lettuce to 3.11 ± 0.49 mg/kg in garlic. Critically, all measured metal concentrations remained within the permissible limits established by the World Health Organization (WHO), implying that consumption of these vegetables and spices poses no apparent risk to human health. Iodine content exhibited significant variability, with African basil (178.50 ± 55.50 μg/g) falling within the advocated range. Smooth amaranth (72.00 ± 9.00 μg/g) and garlic (42.00 ± 19.50 μg/g) presented iodine levels below the guideline, whereas garden lettuce (213.00 ± 85.50 μg/g) exceeded it. The outcomes of this investigation suggest that these vegetables and spices contribute significantly as sources of vital micronutrients in the diet. However, the observed variations in iodine content emphasize the importance of a balanced and diverse dietary intake.

Introduction

1.1 Background

Essential trace substances, especially vital metallic elements like calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), and iodine, are indispensable as they play a fundamental function in maintaining overall human health and physiological balance. These constituents are integral to core biological processes, encompassing osseous formation, catalytic processes, immunological competence, oxygen conveyance, and thyroidal modulation (Ezez et al., 2024). Sufficient intake is paramount for metabolic equilibrium and cognitive function, while insufficiencies can result in conditions such as iron deficiency and thyroid enlargement (Nwokocha, 2024). Conversely, excessive accrual can induce cellular damage from free radicals, thyroid gland impairment, or heavy metal poisoning, emphasizing the necessity for meticulous oversight of nutritional intake (Olusola et al., 2025).

1.2 Problem Statement

While the importance of micronutrients is widely acknowledged, dietary deficiencies remain a global challenge, including within Nigeria. Contemporary research from various Nigerian regions indicates concerns regarding both insufficient nutrient intake and the potential presence of contaminants. For example, Olusola et al. (2025) documented elevated levels of potentially detrimental trace elements in seasonings sourced from Ado Ekiti, while Nwokocha (2024) observed variable iodine concentrations in leafy greens obtained from Owerri. Analogous inquiries conducted in Kogi and Ondo States suggest that crops may accumulate hazardous metals from soil and the application of pesticides (Bello, 2024; Omogbehin & Adehuga, 2024). On a broader scale, occasional instances of exceeding acceptable limits for trace element concentrations in vegetables and seasonings underscore the geographically specific nature of contamination patterns (Ezez et al., 2024).

In the urban area of Kogi, located in North Centra Nigeria, vegetables and spices such as smooth amaranth (*Amaranthus hybridus*), garlic (*Allium sativum*), garden lettuce (*Lactuca sativa*), and African basil (*Ocimum gratissimum*) are critical components of the regular food intake. However, in spite of their nutritional significance, there is a paucity of data concerning their mineral and iodine content. This information gap impedes the development of evidence-based nutritional recommendations and weakens the framework for evaluating potential health risks, particularly in light of increasing apprehensions regarding urban environmental degradation and the use of agricultural inputs in the area.

1.3 Study Objectives

This research endeavors to determine the nutritional and potential health implications related to the presence of key trace elements (calcium, magnesium, iron, zinc) and iodine in common vegetables and seasonings consumed within the Kogi Metropolis region. The investigation is structured around the following primary goals:

I. To measure the levels of these micronutrients through the application of established spectrometric methodologies, specifically employing Atomic Absorption Spectroscopy (AAS) for metal analysis and UV–Visible spectrophotometry for iodine quantification.

II. For comparison purposes, the quantified concentrations should be evaluated against globally accepted dietary benchmarks and safety thresholds, including those established by the World Health Organization (WHO).

III.To assess the dietary value and possible negative health implications arising from the consumption of these plant-based food materials.

The results of this study are anticipated to yield valuable knowledge relevant to the formulation of public health policies, enhancement of consumer understanding, and development of strategies aimed at improving micronutrient availability and addressing potential deficiencies in Nigeria and comparable developing nations.

Materials and Methods

3.1 Chemicals and Reagents

In order to ensure the accuracy and reliability of trace element analysis (Adebayo et al., 2021), meticulous procedures were implemented to minimize potential contamination. All chemical substances utilized were of high purity, meeting established standards for analytical work. Ultrapure water, produced through distillation and deionization, was used consistently in all preparations and processes. Furthermore, all laboratory vessels were subjected to a thorough cleaning protocol. This involved initial washing with a cleansing agent, followed by immersion in a strong acidic solution, multiple rinses with ultrapure water, and finally, drying in a temperature-controlled oven at 40 °C prior to use.

3.2 Sample Collection

In this study, four frequently ingested plant specimens were chosen for analysis: two leafy greens, *Amaranthus hybridus* and *Lactuca sativa* and two flavoring agents, *Allium sativum* and *Ocimum gratissimum* . The leafy green specimens were collected directly from agricultural lands situated in Osara, proximal to Osaran-gada Road, Kogi. Conversely, the flavoring agents were procured from a neighboring commercial marketplace. Definitive identification and verification of all plant samples were conducted at the Herbarium Division within the Department of Plant Biology, Confluence University of Science and Technology Osara. Representative voucher specimens were subsequently archived at this location for future comparative examination.

3.3 Sample Preparation

Following collection, the samples underwent a rigorous cleaning procedure. Initially, they were subjected to extensive washing with potable water, succeeded by rinsing with deionized water, in order to eliminate adhered soil and superficial contaminants. Subsequently, the samples were desiccated in a drying oven maintained at 40°C until a stable mass was attained. Upon reaching room temperature, the dried samples were processed into a homogenous, fine particulate matter via manual comminution with a mortar and pestle. The resulting powder was then fractionated using a sieve to ensure uniformity in particle dimensions. Finally, the prepared samples were preserved in hermetically sealed receptacles, awaiting future investigative analyses (Oladeji et al., 2022).

3.4 Formulation of Standard Solutions

3.4.1 Metal Standards

In order to generate calibration references for later analytical procedures, stock solutions **of calcium, magnesium, iron, and zinc**, each formulated at **a** concentration **of** 1000 mg/L, were prepared. This was achieved by dissolving precisely measured quantities of the appropriate salts in deionized water within 1000 mL volumetric flasks. The specific masses of salts utilized were as follows:

- Calcium was incorporated into the solution using precisely 4.2924 g of **calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$)**;

- Magnesium was supplied in the preparation through the use of 8.4633 g of **magnesium chloride hexahydrate ($MgCl_2 \cdot 6H_2O$)**.;
- Iron as 4.9787 g of ferrous sulfate heptahydrate ($FeSO_4 \cdot 7H_2O$);
- Zinc as 4.5501 g of zinc nitrate hexahydrate ($Zn(NO_3)_2 \cdot 6H_2O$).

To generate a range of working standards, serial dilutions of these stock solutions were performed, resulting in a concentration gradient spanning from 0 to 10 mg/L.

3.4.2 Iodine Standard

To create a standardized iodine concentrate with a concentration of 1000 mg/L, a specific procedure was followed. Initially, 13 grams of solid iodine were dissolved within 100 mL of a potassium iodide (KI) preparation. This KI preparation was made by dissolving 25 grams of KI into 100 mL of purified water. Following dissolution, the resulting mixture was brought to a final volume of 1 liter using purified water and subjected to complete agitation to ensure a uniform distribution of iodine throughout the solution (Fasakin et al., 2023).

3.5 Sample Digestion

For each powdered sample, a precisely measured quantity of two grams was weighed and introduced into individual beakers. The samples were subsequently subjected to chemical decomposition through an acid digestion procedure, employing a mixture of concentrated **nitric acid and hydrochloric acid**, blended **in a** volumetric **ratio of 1:3**. This digestion was carried out on a hot plate, with heating continued until the samples dissolved, resulting in visually clear solutions. Following a cooling phase, the digested samples were diluted with 40 mL of deionized water and subsequently clarified through filtration. The resulting filtrates were then quantitatively transferred to 100 mL volumetric flasks. Concurrently, control digestions, devoid of the sample material, were performed under identical procedural parameters. The concentrations of calcium, magnesium, iron, and zinc in the prepared solutions were determined using **a Buck Scientific Model 210 VGP Atomic Absorption Spectrophotometer**, in accordance with standardized analytical protocols (Akinola et al., 2021; Bello et al., 2024).

3.6 Determination of Iodine

Iodine content was assessed following a refined alkaline dry ashing procedure. In summary, about 0.5 grams of each finely ground sample was incinerated in a muffle furnace with the aid of sodium hydroxide **(0.5 M) and potassium nitrate (0.1 M)**. The resulting ash was then solubilized in a 1 mM sodium hydroxide solution, followed by centrifugation at 3000 rpm for 20 minutes to separate insoluble components. The supernatant was carefully recovered and subjected to spectrophotometric analysis. Iodine quantification was achieved via the Sandell–Kolthoff reaction, with absorbance measurements taken at 353 nm using a PerkinElmer UV–Visible spectrophotometer, as per established methodologies (Adeyeye & Ogunlade, 2022; Zhang et al., 2023).

RESULTS AND DISCUSSION

4.1 Results

Table 4.1. Concentration of selected metals (mg/kg) in edible leafy vegetables compared with WHO and NESREA limits.

Sample	Calcium(mg/kg)	Magnesium(mg/kg)	Iron (mg/kg)	Zinc (mg/kg)
Amaranthus hybridus	72.23 ± 9.62	74.56 ± 0.41	2.17 ± 0.00	1.98 ± 0.49
Ocimum gratissimum	94.33 ± 9.82	63.46 ± 0.91	7.25 ± 1.93	2.83 ± 0.49
Lactuca sativa	61.00 ± 9.62	56.72 ± 1.23	5.07 ± 0.97	1.41 ± 0.49
Allium sativum	122.22 ± 9.62	52.15 ± 0.93	7.25 ± 0.97	3.11 ± 0.49
WHO Limit (RDA)	1000	420	8	11
NESREA Limit	–	60	5 (not fixed)	5

Key:

WHO = World Health Organization

RDA = Recommended Daily Allowance

Table 4.2. Absorbance and concentration of selected vegetables compared with WHO permissible limits.

Sample	Absorbance	Concentration (µg/g)
Amaranthus hybridus	0.048	72.00 ± 9.00
Ocimum gratissimum	0.119	178.50 ± 55.50
Lactuca sativa	0.142	213.00 ± 85.50
Allium sativum	0.028	42.00 ± 19.50
WHO Limit	–	150–200

Key:

WHO = World Health Organization

RDA = Recommended Daily Allowance

4.2 Discussion

4.2.1 Essential Metals in Vegetables and Spices

Table 4.1 presents the concentrations of Calcium (Ca) which decreased in the following order: *Allium sativum* > *Ocimum gratissimum* > *Amaranthus hybridus* > *Lactuca sativa*. Conversely, Magnesium (Mg) concentrations exhibited an inverse trend, increasing as follows: *Allium sativum* < *Lactuca sativa* < *Ocimum gratissimum* < *Amaranthus hybridus*. Iron (Fe) levels were highest in *Allium sativum*, followed sequentially by *Ocimum gratissimum*, *Lactuca sativa*, and *Amaranthus hybridus*. The distribution of Zinc (Zn) displayed a comparable pattern, with concentrations diminishing in the sequence *Allium sativum* > *Ocimum gratissimum* > *Amaranthus hybridus* > *Lactuca sativa*.

Comparison with existing literature provides a framework for interpreting these results. For instance, the higher Ca concentrations observed by Oladeji et al. (2022) in similar leafy vegetables suggest that geographical or agricultural variables influence accumulation rates. The diminished values noted in the present investigation may be attributable to variations in soil nutrient profile or specific cultivar traits. The Mg concentration in *Amaranthus hybridus* in this study (74.56 ± 0.41 mg/kg) was substantially less than the levels recorded by Bello et al. (2024), who reported figures exceeding 200 mg/kg in related species. Such disparities likely stem from differences in soil characteristics or fertilization regimes.

Iron levels generally aligned with the higher values reported by Akinola et al. (2021) for *Allium sativum* in a different region, reaffirming its value as a beneficial source of dietary Fe . The Zinc content, particularly in *Lactuca sativa* (1.41 ± 0.50 mg/kg), was lower than previously documented values for local *Amaranthus* and *Ocimum* species (approximately 4–5 mg/kg) (Adeyeye et al.,2022). Notwithstanding these regional differences, all measured metal concentrations remained below the safety thresholds established by the WHO and NESREA, indicating that these food sources are safe for human intake.

4.2.2 Iodine Content in Examined Samples

As demonstrated in Table 4.2, Iodine (I) concentrations across the analyzed samples were ranked as follows: *Lactuca sativa* > *Ocimum gratissimum* > *Amaranthus hybridus* > *Allium sativum* (213.00 ± 85.50, 178.50 ± 55.50, 72.00 ± 9.00, and 42.00 ± 19.50 µg/g, respectively).

Only *Ocimum gratissimum* exhibited Iodine levels within the WHO-recommended range (150–200 µg/g). The increased Iodine concentration in *Lactuca sativa* may reflect local soil enrichment or the presence of environmental Iodine sources, a trend consistent with observations by Nwokocha (2024), who documented considerable variability in Iodine levels in vegetables, even within a confined geographical area. Conversely, the reduced values in *Amaranthus* and *Allium* contrast with previous findings by Salau et al. (2011), who documented augmented Iodine levels in *Amaranthus hybridus* and a typical range of 94–118 µg/100 g in other vegetables. Discrepancies in units (µg/g vs. µg/100 g) and geographic variability likely contribute to this difference.

The elevated Iodine concentration in *Lactuca sativa* may present a potential risk of excessive consumption, particularly for populations with high dependence on this vegetable. Iodine content in plants is known to reflect Iodine concentrations in the soil and environmental deposition patterns (Fuge, 2020). Considering these observations, dietary guidelines should account for both deficiency and excess risks, especially among iodine-sensitive subpopulations.

4.2.3 Implications for Human Health and Safety

The detected levels of Ca, Mg, Fe, and Zn were consistently lower than globally accepted safety thresholds, indicating that the consumption of these vegetables and spices is considered safe from a heavy-metal exposure standpoint. Iodine levels, however, displayed considerable variability. While *Ocimum gratissimum* exhibited an optimal Iodine range, the increased concentration in *Lactuca sativa* and reduced levels in *Amaranthus* and *Allium* emphasize the importance of dietary diversity to ensure the safe and sufficient intake of micronutrients.

Conclusion and Recommendations

This research investigated the concentrations of several essential minerals, including calcium, magnesium, iron, zinc, and iodine, in frequently consumed vegetables and spices within the Kogi Metropolis area of Nigeria. The results indicated considerable differences in micronutrient concentrations among the examined plant types. Concentrations of calcium, magnesium, iron, and zinc were generally found to be at acceptable levels. However, iodine concentrations exhibited substantial variations: African basil (*Ocimum gratissimum*) fell within the range recommended by the World Health Organization (WHO), lettuce (*Lactuca sativa*) surpassed the maximum limit, and both amaranth (*Amaranthus hybridus*) and garlic (*Allium sativum*) demonstrated relatively low values. These variations emphasize the significant impact of soil characteristics, cultivation methods, and environmental factors on mineral uptake by plants. This observation supports recent literature indicating that geographical and ecological variables are strong determinants of nutrient variability in food crops (Abdu et al., 2022; Ezeh et al., 2023).

The detected variations have substantial implications for nutrition and public health. Sufficient consumption of calcium, magnesium, and zinc is crucial for metabolic processes, nerve and muscle function, and immune system activity. Conversely, both insufficient and excessive iodine intake can lead to thyroid issues and related health problems (WHO, 2022; Morshed et al., 2023). Consequently, the findings underscore the dual nature of commonly consumed vegetables: they serve as important sources of vital micronutrients, but may also represent potential dietary hazards if consumed without sufficient dietary variation.

Recommendations

This research underscores the importance of a multi-faceted approach to ensure optimal micronutrient intake through vegetable consumption, particularly in regions with limited resources.

Firstly, continuous nutritional surveillance is crucial. Ongoing monitoring of trace and essential element levels in locally grown produce is advisable to protect dietary adequacy and population well-being.

Secondly, promoting dietary variety is recommended. Educational initiatives focused on nutrition should advocate for the consumption of a wide range of vegetables. This strategy helps ensure a balanced intake of micronutrients and reduces the potential for deficiencies or excessive accumulation of specific elements (Adeboye et al., 2021).

Thirdly, comprehensive environmental evaluations are needed. Future investigations should incorporate analysis of soil composition, irrigation water sources, and fertilizers used. This more holistic assessment will improve our understanding of the factors contributing to nutrient variations observed in plant tissues, with specific attention to iodine (Zhang et al., 2024).

Fourthly, strategic policy development is essential. Public officials should develop geographically tailored dietary recommendations for key micronutrients, particularly iodine, acknowledging its inherent variability and its critical role in maintaining healthy thyroid function (WHO, 2022).

Finally, integrating food security initiatives is vital. Given the nutritional significance of local vegetable species, sustainable farming practices and potential nutrient enhancement strategies should be incorporated into broader agricultural and food security frameworks.

In conclusion, while the investigated vegetables are considered safe for eating, their variability in mineral content necessitates a context-sensitive dietary approach that carefully weighs nutritional advantages against potential health considerations. Enhancing the connection between agricultural practices, food attributes, and public health regulations will be paramount in optimizing micronutrient intake in resource-scarce environments.

References

1. Abdu, N., Haruna, A., & Musa, R. (2022). Soil–plant interactions and trace element accumulation in vegetables cultivated in northern Nigeria. *Environmental Monitoring and Assessment, 194*(3), 185. https://doi.org/10.1007/s10661-022-09872-4
2. Adebayo, A. R., Usman, M. T., & Musa, H. (2021). Quality assurance in trace metal analysis of vegetables using acid-washed glassware. *Journal of Analytical Chemistry Research, 18,* 45–53. https://doi.org/10.1016/j.jacr.2021.03.005
3. Adeboye, O. C., Ogunjimi, L. A., & Adebayo, A. (2021). Dietary diversification and micronutrient adequacy among Nigerian households. *Public Health Nutrition, 24*(12), 3729–3739. https://doi.org/10.1017/S1368980021000543
4. Adeyeye, E. I., & Ogunlade, I. (2022). Nutritional evaluation of iodine and essential minerals in Nigerian vegetables and condiments. *Food Chemistry Advances, 7,* 100181. https://doi.org/10.1016/j.focha.2022.100181

5. Akinola, O. O., Ibrahim, M. S., & Ajayi, K. O. (2021). Comparative study of wet digestion methods for heavy metal determination in food crops using AAS. *Scientific African, 14,* e00926. https://doi.org/10.1016/j.sciaf.2021.e00926
6. Bello, U., Haruna, M., & Yahaya, A. (2024). Assessment of mineral and toxic metal residues in edible vegetables from peri-urban farms in northern Nigeria. *Heliyon, 10*(2), e25417. https://doi.org/10.1016/j.heliyon.2024.e25417
7. Emurotu, J. E., Emurotu, O. M., Ipeaiyeda, A. R., & Onianwa, P. C. (2024). Assessment and bioaccumulation of metals in parts of crops from farmland environment and their health risk, Kogi State North-central Nigeria. *Chemistry Africa, 7*(5), 3361–3375. https://doi.org/10.1007/s42250-024-00923-4
8. Ezeh, C. I., Nwachukwu, M. I., & Ugwu, A. M. (2023). Variability of mineral composition in indigenous vegetables: Influence of agro-ecological zones in West Africa. *Journal of Food Composition and Analysis, 115,* 105058. https://doi.org/10.1016/j.jfca.2023.105058
9. Ezez, C., Danladi, J., & Okafor, V. (2024). Heavy metal accumulation and health risk assessment in commonly consumed vegetables: A global perspective. *Environmental Monitoring and Assessment, 196*(7), 550–563. https://doi.org/10.1007/s10661-024-1205-7
10. Ezez, D., Oladeji, O., et al. (2024). Bioaccumulation of heavy metals, assessment of carcinogenic and non-carcinogenic health risk in various spices. *Journal of Hazardous Materials Advances, 15,* 100441. https://doi.org/10.1016/j.hazadv.2024.100441
11. Fasakin, O., Olumide, A., & Lawal, A. (2023). Optimization of iodine determination in food samples using spectrophotometric methods. *Food Analytical Methods, 16,* 1075–1086. https://doi.org/10.1007/s12161-023-02614-2
12. Fuge, R. (2020). The influence of environmental iodine and local geological factors on dietary iodine intake. *Applied Geochemistry, 115,* 104538. https://doi.org/10.1016/j.apgeochem.2020.104538
13. Morshed, S. A., Choudhury, M., & Islam, M. T. (2023). Iodine intake and thyroid function: A global perspective on deficiency and excess. *Nutrients, 15*(4), 895. https://doi.org/10.3390/nu15040895
14. Nwokocha, G. C. (2024). Evaluation of iodine and goitrogens in selected vegetables from Owerri, Imo State, Nigeria. *Asian Journal of Biochemistry, Genetics and Molecular Biology, 16*(6), 81–88. https://doi.org/10.9734/ajbgmb/2024/v16i6385
15. Nwokocha, O. (2024). Variability of iodine and goitrogen content in vegetables cultivated in Owerri, Nigeria. *Food Chemistry Advances, 3*(1), 100215. https://doi.org/10.1016/j.focha.2024.100215
16. Oladeji, O. S., Jimoh, I. O., & Yakubu, M. A. (2022). Evaluation of mineral composition in selected Nigerian green leafy vegetables. *BMC Chemistry, 16,* 118. https://doi.org/10.1186/s13065-022-00872-5
17. Olusola, A., Adebayo, S., & Kareem, T. (2025). Trace metals in culinary spices from Ado Ekiti, Nigeria: Implications for food safety. *Scientific African, 21,* e02145. https://doi.org/10.1016/j.sciaf.2025.e02145

18. Olusola, J. A., Akintan, O. B., & Osanyinlusi, O. (2025). Trace metals potential human health risks assessment through consuming common food spices in Ado Ekiti, Southwest, Nigeria. *Journal of Trace Elements and Minerals.* Advance online publication. https://doi.org/10.1016/j.jtemin.2024.100208
19. Omogbehin, O., & Adehuga, F. (2024). Pesticide residues and trace metal contamination in fruits and vegetables from Ondo State markets, Nigeria. *Heliyon, 10*(6), e30652. https://doi.org/10.1016/j.heliyon.2024.e30652
20. Omogbehin, S., & Adehuga, S. (2024). Evaluation of pesticides and trace metal contaminants in grains, fresh fruits and vegetables from Odoluwa Market, Ile Oluji, Ondo State, Nigeria. *International Research Journal of Pure and Applied Chemistry, 25*(3), 1–13. https://doi.org/10.9734/irjpac/2024/v25i3851
21. Salau, A. B., Ajani, E. O., Soladoye, M. O., & Bisuga, N. A. (2011). Evaluation of iodine content of some selected fruits and vegetables in Nigeria. *African Journal of Biotechnology, 10*(6), 960–964. https://doi.org/10.5897/AJB10.11
22. World Health Organization. (2022). *Guideline: Fortification of food-grade salt with iodine for the prevention and control of iodine deficiency disorders.* WHO.
23. Zhang, L., Chen, J., & Wu, Y. (2023). Advances in iodine determination in food matrices using UV–Vis spectrophotometry. *Food Chemistry, 412,* 135486. https://doi.org/10.1016/j.foodchem.2023.135486
24. Zhang, Y., Li, W., & Chen, H. (2024). Environmental drivers of iodine content in food crops: Implications for nutrition security. *Science of the Total Environment, 905,* 167381. https://doi.org/10.1016/j.scitotenv.2023.167381

Figures

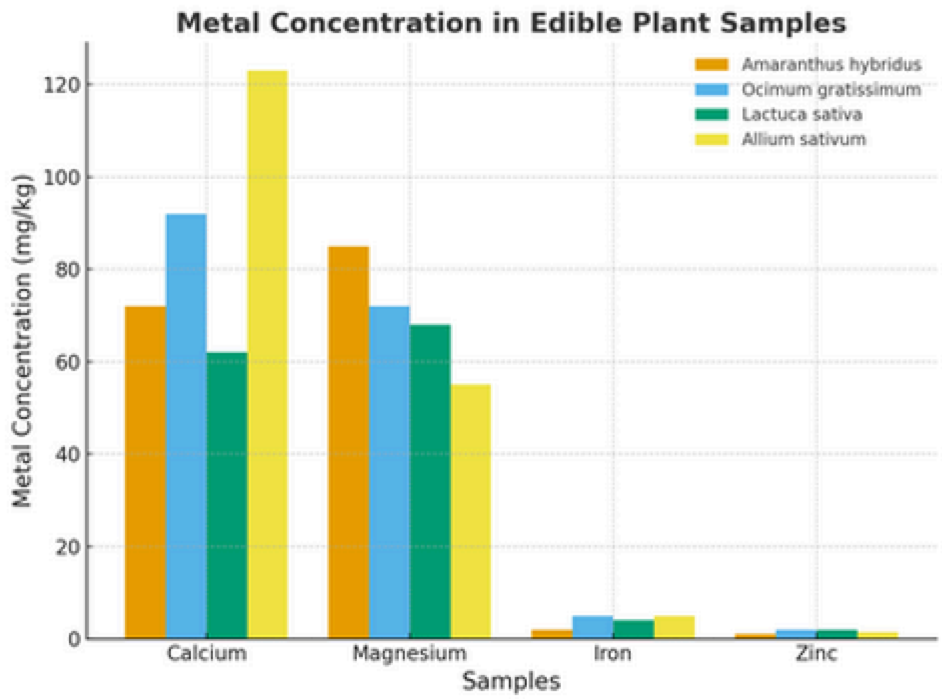

Figure 1

Figure 4.1: Concentration of the metals in the Samples